

AVIONICS magazine TECH REPORT

LED PUSH-BUTTON SWITCH LIGHTING:

A Successor to Incandescent



Because the aircraft industry seeks high reliability, it began a push in the late 1980s for light emitting diode

(LED) lighting to replace the failure-prone incandescent lamps. Aircraft operators thought that by using long-life LEDs, the problem of replacing failed incandescent lamps could be minimized. So in the early 1990s, some lighted push-button switch manufacturers began using flange-based LEDs, inserted into their push-button caps in place of the flange-base incandescent lamps.

However, since these push-button caps were designed originally to work with incandescent lamps, the introduction of flange-based LEDs resulted in bad switch legend lighting. Illumination of the legend, or writing on the button, was not uniform; the light created a bright “hot spot” in the legend directly over the LED and almost no lighting in the legends adjacent to the “hot spots.”

Since all the light was being focused forward, the legends were totally unreadable when viewed off the perpendicular axis. Also, the LEDs had series resistors to operate at 28 volts DC but went out when the voltage was dimmed to night settings, so the LED light offered no real dimming capability.

Overcoming LED Problems

Aerospace Optics has overcome hidden cockpit problems with its VIVISUN LED switch designs. Each of its LEDs requires in excess of 750 microamps of current before a switch legend illuminates, thereby eliminating the possibility of inadvertent legend illumination. The power consumption is 1.18 watts for a full-face legend, which produces little heat, resulting in a low face-cap touch temperature. The LEDs’ full-on luminance is 300 to 600 footlamberts, providing sunlight readability. And they have voltage controlled dimming to allow dimming down to 10 to 30 footlamberts and down to 0.1 footlamberts for special NVIS-compliant lighting.

The reliability for the VIVISUN LED lighting is 125,000 hours at 60 degrees C, compared with 2,500 hours for incandescent, and the fault-tolerant design allows legends to be read even if an LED does fail. The LED circuits are protected from voltage transients and will meet all of the DO-160 electrical environment requirements, including power input, voltage spikes, lightning-induced transients, electrostatic discharge, and both radiated and conducted radio frequency emissions and susceptibility. The LED brightness is stabilized over the entire operating temperature range of -40 to 71 degrees C with less than a 20 percent variance in luminance over the entire operating range.

In addition, the colors available to LEDs were limited; the lighting could not be obtained in blue, green or white, which are widely used in advisory lights in cockpits. These problems were so bad that LED lighting received a bad reputation from engineers who tried to adapt them to cockpit applications.

Incandescent lamps have been used in lighted push-button switches to pres-



LED switches are fully NVIS-compliant.

ent legends bright enough to be viewable through a 90-degree included angle and dimmable by simply reducing the applied voltage. However, incandescent lighting, which is produced by heating a filament, requires high power consumption. It also generates so much heat that touching the push-button switch cap can be painful for a pilot not wearing gloves.

Long-Life LEDs

Lighted push-button switches, such as the VIVISUN LED made by Aerospace Optics, an AS9100 registered lighting technology company, eliminate the heat problems. They use less than half the power of incandescent lamps (1.18 watts vs. 2.68 watts) and employ an optical design that still produces high brightness, sunlight readable legends that are uniform and viewable through a 90-degree included angle.

In the case of the VIVISUN LED, a patented circuit design provides voltage-controlled dimming, so reducing the applied voltage can dim the lighting. In a cockpit environment, incandescent lamps have a much shorter rated life because of the high heat they generate and the shock and vibration to which they are subjected. Replacing incandescent lamps in a cockpit can be almost a daily job.

LEDs do not produce the high heat environment and are solid state, so they are relatively immune to shock and vibration. This performance, combined with a 100,000-hour operating life and fault-tolerant circuit design, can result in switch light that lasts an aircraft’s full life. Switch lighting may never have to be replaced on an aircraft.

The new LEDs also have led to new design possibilities that could not have been achieved with incandescent lamps. For example, Aerospace Optics has developed a true-blue lighted switch legend color that has luminance levels in excess of 300 footlamberts, making legends sunlight readable. And when dimmed to 0.1 footlamberts, it complies with the night vision imaging system (NVIS) radiance requirement of $NR < 1.7 \times 10^{-10}$. This cannot be done with incandescent lighting.

Also, an NVIS white switch legend color has been developed that is sunlight readable and complies with the Mil-Std-3009 NVIS radiance requirement of $NR < 1.0 \times 10^{-9}$ when dimmed to 0.1 footlamberts. What is prominent about the feature is that the color is truly a “white white.” And, again, this cannot be achieved with incandescent lamps, which, at best, can produce a light green color that is claimed to be white. LED lighting maintains good color separation even when dimmed to very low luminance levels, where incandescent blues turn white and whites turn yellow, confusing the pilot as to what color he actually is seeing in night flying conditions.

Another advance from Aerospace Optics is in luminance uniformity from color to color when the switch legends are dimmed. This means that when four different colored legends appear on a single switch cap, they can be dimmed without one color extinguishing before the others have been dimmed sufficiently.

Push-button switches with LED lighting include the necessary driving, dimming and protection circuitry. Lighting produced by Aerospace Optics, for example, provides a mean time to failure (MTTF) of 125,000 operational hours, as calculated by the guidelines of Mil-HDBK-217 at 60 degrees C for an airborne inhabited fighter.

Overcoming Problems

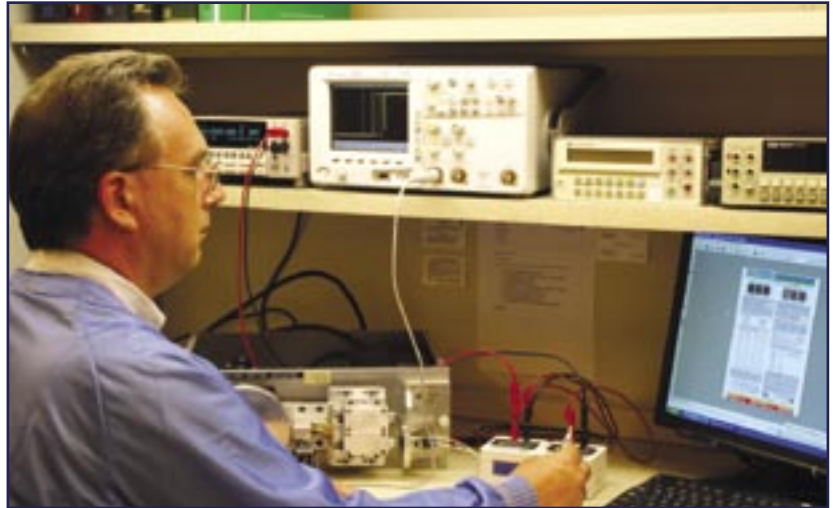
LEDs, as current-driven devices, begin to illuminate with only a few microamps

of current. Some avionics can induce 200 to 300 microamps of leakage current onto the switches causing the lighted legends to be unintentionally illuminated to luminance levels of 7 footlamberts. Since night flying luminance levels are typically 15 footlamberts, pilots therefore could become confused by legends that are inadvertently illuminated.

Such an unsafe condition can be avoided with LED lighted switches, provided they are designed to require a minimum of 750 microamps before producing a barely discernable luminance (less than 0.05 footlamberts). This will prevent any inadvertent legend illumination.

Another safety-related issue is the use of LEDs that are electrically connected in series. Some suppliers have as many 12 LEDs connected in series to illuminate a single legend. If a failure results in an open circuit, all 12 LEDs will go out, and the legend will not illuminate. It therefore is imperative that a design include built-in fault tolerance, in the remote chance that a failure does occur.

Fault tolerance can be achieved by having LEDs separated into at least two electrically independent circuits for each lighted legend. With such a configuration, if one LED fails, the other will continue to partially illuminate the legend. Fault tolerance also can be achieved for LEDs connected in a series circuit by designing additional electrical circuits, which will provide route-around electrical paths



Extensive lab work has vastly improved LED technology.

that circumvent any potential open-circuit failures within the series circuit.

Another concern related to LEDs is operating voltage. LEDs typically operate in a voltage range of 2 to 4 volts DC maximum. However, the typical operating voltage for aircraft cockpit switch legends, annunciators and indicators is 28 volts DC. This huge difference in driving voltage would burn out all LEDs that were not designed to be driven at 28 volts DC. The LEDs can be arranged in series to require a higher driving voltage.

Electrical Protection

Aircraft cockpits and their avionics do not just “see” 28 volts DC operating voltage. They also are subjected to all kinds of

transients from power supplies, generators, contactors, lightning-induced currents, conducted emissions, radiated emissions and electrostatic discharge. LEDs are extremely susceptible to these conditions and are electrically quite fragile—easily burned out by transients.

As a result, any LED circuit design must include electrical protection from voltage transients. As a minimum, any LED lighted push-button switch must operate in the extreme electrical environments described in DO-160 without suffering damage. DO-160 normal power input is 18 to 30.3 volts DC; however, normal surges can reach 50 volts DC and abnormal surges can be as high as 80 volts DC.

Programmable Push-Button Switches

As technology has advanced, cockpits have become filled with multifunction displays that replace the arrangements of individual instruments. The result is what we now call the “glass” cockpit. In efforts to further reduce the number of components on the instrument panel, engineers have tried to eliminate individual push-button switches by placing the switching functions on touchscreens over the multifunction display.

This created problems. For example, touching a screen brought no tactile feedback to signal that the pilot had, in fact, actuated the touchscreen. Lighted push-button switches, therefore, have been put back into the cockpits, both on the instrument panel and on the avi-

onic black boxes. Now these individual switches are being replaced in order to save panel space.

To help reduce the number of switches, Aerospace Optics has developed the Dichromatic switch, which allows one switch to perform the function of two. These switches have legends that can be programmed to illuminate in more than one color. When these programmable color legends are combined with an always visible white legend, presentation of as many as six different functions can be displayed on a single switch.

Aerospace Optics also has developed a programmable legend push-button switch that uses a 16-by-35 LED pixel array, capable of displaying various

text messages and graphics patterns, depending on their programming. These programmable multifunction push-button (PMP) switches can replace large numbers of dedicated function switches and annunciators. They thereby reduce required panel space and make the man/machine interface between the pilot and airplane much more efficient and interactive.

The PMPs have a crisp snap-action, tactile feel that gives the pilot an affirmative signal that the switch has been activated. The development of new types of lighted push-button switches with NVIS lighting will become aligned with new cockpit designs of the future, as homeland security becomes a greater priority for the nation.

The LED lighted switch legends must also continue to operate when hit with voltage spikes of 600 volts, an electronic static discharge (ESD) of 15,000 volts, and pin injection lightning induced transients defined in DO-160 waveform 3 of 600 volts at 24 amperes and waveform 4 of 300 volts at 60 amperes. Further, the LEDs have to be protected from conducted emissions of 20 volts per meter from 10 kHz to 400 MHz and 150 volts per meter (pulse) from 400 MHz to 8 GHz. Also, the LED lighted switches must meet the magnetic effects, audio frequency conducted susceptibility, induced signal susceptibility, and emission of radio frequency energy requirements of DO-160.

Historically, one of the limitations of LED lighted switches has been achieving sunlight readable legend luminance equivalent to incandescent lighting. To increase LED brightness, most manufacturers have made a poor design decision by reducing the number of LEDs to reduce cost, then significantly increasing the LED current to achieve higher brightness. This practice severely reduces the life of the LEDs, defeating one of the primary reasons for using LEDs—long life. Also, it actually can

exceed the required derating of the LED current in elevated temperature operation of 71 degrees C. Typically LED intensity is stated in millicandelas at 20 milliamps of current at room temperature.

In addition, the practice of increasing LED current to achieve brightness can lead to an LED “runaway” condition. In this case, increasing current leads to increasing junction temperature, which in turn leads to more current and a severe decline in LED brightness to less than 45 percent of its original output. One can observe the runaway condition by placing an LED lighted legend in front of a properly calibrated photometer and measuring the legend luminance immediately when energized. The luminance then can be observed to drastically drop with time, as the LED junction temperature begins to rise.

While the goal for LED lighting is 300 to 600 footlamberts of luminance at 28 volts, there also has to be a designed-in capability for dimming to the typical night flying luminance levels of 10 to 30 footlamberts. This level was originally established by reducing the voltage of incandescent lighted switches to 14 volts,

half of their 28-volt rated voltage. Since LED lighting is designed to replace incandescent lighting, it follows that an LED switch legend needs to produce comparable luminance, i.e., the LED lighting has to be designed to operate at the voltages originally established for dimming aircraft lighting using incandescent lamps.

The highly anticipated introduction of LED technology into aircraft cockpit lighting has finally become a reality. It has come along with the most innovative and sophisticated lighted push-button switches since their inception in the 1950s. After 40 years of incandescent dominance, LED lighted push-button switches have been proven to have amazing reliability, Mil-Spec quality and lighting that rivals and often surpasses incandescent lighting.

Products such as the VIVISUN LED lighted push-button switches are fully qualified to the MIL-PRF-22885/108 military specification, DSCC approval and listed on the Qualified Products List, QPL-22885. Aerospace Optics claims it can provide seven-day, on-time delivery, zero-defect quality and flexibility in design.

100%

MIL-PRF-22885/108 qualified = QPL 22885 listing



At Aerospace Optics we don't treat MIL-SPEC as an option. Every VIVISUN LED sunlight readable switch is designed, tested and qualified to meet 100% MIL-PRF-22885/108 and MIL-STD-3009 for NVIS compliance. Delivered in seven days, VIVISUN LED switches feature AC or DC voltage-controlled dimming, maintenance free field performance and are available in 11 sunlight readable colors. Aerospace Optics is committed to earning your business by building relationships based on personal attention, trusted delivery and quality products. For 100% MIL-SPEC LED switches, call today or visit www.vivisun.com.

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